Human-Machine Teaming for Stand-off Triage

AI-Driven Decision Support in Battlefield Medicine



Robotics Institute



DARPA Triage Challenge: Why It Matters



In addition to the battlefield, the Emergency Events Database recorded a total of **86,473 fatalities** and **93.1 million people** affected in 2023.

https://files.emdat.be/2024/04/CredCrunch74.pdf





Reducing Risk to Human Responders and Speeding Up Triage and Rescue



Stand-off triage

Approach:

A fleet of autonomous drones and ground robots, equipped with cuttingedge multi-modal sensors, continuously scans the disaster zone. These platforms employ compact, low-SWaP sensor packs and adaptive navigation algorithms to maneuver safely and precisely through chaotic, post-disaster environments.

Goal:

The primary objective is to rapidly identify disaster casualties by autonomously detecting critical physiological signatures—such as heart rate, respiratory distress, and visible injury markers—without direct contact. The integrated sensor suite is optimized for stand-off assessment, ensuring reliable victim condition evaluation even in challenging settings.

Means:

Advanced processing algorithms fuse data from thermal, visual, radar, and audio sensors using Bayesian inference and machine learning techniques. This concatenated and validated output supports real-time triage decision-making and prioritizes interventions for lifesaving treatments.

Challenges:

Effective triage is impeded by hazards at the disaster site including unstable structures, toxic materials, and extreme environmental conditions. Additional challenges involve reliably accessing and accurately assessing dynamically moving casualties in degraded sensing scenarios and ensuring uninterrupted, secure communications under high interference.

DoD 2025 Relevance

Challenges:

- 1. High Cognitive and Physical Load on Medics:
 - 1. Field medics must assess **multiple casualties** in **chaotic conditions**.
 - 2. Decisions are based on **rapid**, **imprecise observations** (e.g., visible injuries, breathing patterns).
- 2. Responder Risk in Hostile Environments:
 - 1. Medics often operate in active firefights or CBRN (chemical, biological, radiological, nuclear) environments.
 - 2. Stand-off assessment reduces the need for direct exposure.
- 3. Delays in Evacuation & Prioritization:
 - 1. Without **real-time vitals and injury severity estimation**, casualty evacuation (CASEVAC) may be inefficient.
 - 2. Non-visible injuries (internal bleeding, shock, concussions) are often missed.



Human-System Integration Ensures Effective AI & Robotics Integration

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			HSI Domain	Application in AI-Driven Combat Medicine	
NDIA Vital Signs 2025 Key Findings:	Human Systems Integration (HSI)	HSI is governed by DoDI 5000.95	Human Factors Engineering	Ensuring user-friendly AI interfaces that provide clear, interpretable recommendations to medics/client	
Workforce shortages in	A multidisciplinary	HSI ensures that warfighters, medical personnel, and autonomous systems work together in high stakes environments	Manpower and Personnel	Reducing the medic-to-casualty ratio, allowing small teams to better handle MCI's	
(63% reported difficulty hiring)	developing, and deploying systems that optimize		Training	Simulating AI-assisted triage scenarios to build trust and familiarity	
Al adoption in defense is underutilized (70% report less than 15% use in operations)	safety, and effectiveness		Safety and Survivability	Ensuring AI decisions are reliable and explainable to prevent false positives/negatives in injury detection and decompensation	
Supply chain bottlenecks in medical tech & electronic components			Occupational Health	Reducing medic fatigue by automating time-consuming assessments	

Art of the Doable?



Hypothesis:

- Al-assisted triage may complete assessments in 5 minutes or less vs. 15 minutes reducing triage time by ~66%.
- AI may improve accuracy by ~20% in predicting injury severity vs. human medics whose performance accuracy is impacted by fatigue and cognitive overload.
- Al might reduce errors by ~67%, increasing reliability.
- If AI-based triage has a 5% error rate, primarily due to sensor & model limitations (e.g., occlusion, false positives) & Human-only triage has a 15% error rate, stemming from stress, misinterpretation, and limited data access, we can increase accuracy.

[1] Defense Advanced Research Projects Agency (DARPA), "DARPA Triage Challenge Documentation (2024-2025)," DARPA Triage Challenge Resources, 2024. Available: https://triagechallenge.darpa.mil/resources.

[2] U.S. Army Institute of Surgical Research, "AI for Battlefield Medicine Report (2023)," U.S. Army Medical Department, 2023. Available: https://usaisr.health.mil/.

[3] U.S. Department of Defense, "DoD Medical AI Readiness Study (2024)," 2024. Available: https://health.mil/News/Dvids-Articles/2025/01/08/news488829.

[4] Guardian Centers, "Guardian Center RDAX Field Trial Reports (2024)," 2024. Available: https://www.youtube.com/watch?v=d3jWORL8ors.

[5] National Institute of Standards and Technology (NIST), "AI-Enabled Combat Medicine White Paper (2023)," Army Medicine and Artificial Intelligence: Transforming the Future of Battlefield Care, 2023.

Available: https://www.armyupress.army.mil/Journals/Military-Review/English-Edition-Archives/May-June-2024/MJ-24-Army-Medicine-Al/.

Mission Objective: Autonomous Navigation, Multimodal Sensing, &









• Learning-based Multi-modal SLAM using large diverse simulation data

AI Based Diagnostics









- Off-road autonomy:
- Estimate traversability without human labeled data
- Online adaptation / exploration

IRef-VLA: A Benchmark for Interactive Referential Grounding With Imperfect Language in 3D Scenes



Haochen Zhang, Nader Zantout, Pujith Kachana, Ji Zhang, Wenshan Wang





(a) Scene with scene graph

"The white bed that is between the other bed and the door frame"

(b) Referential statement

• Visual-language navigation:

representation

- Semantic scene representation, spatial reasoning
- Understand language instructions and give feedback

Robot Front End Perception (Foundation) Model

Match objects inside images is a fundamental capability that can help robot perception

- b frank



Various Platforms



Various Camaras

ANYTHING

Match Anything (Foundation) Model



Vital Signs Detection & AI-Enabled Decision Support



0.16	dx signal				
0.18 -	0.2	0.4	0.6	0.8	1.0
0.4 -		dy s	ignal		
0.3	0.2	0.4	0.6	0.8	1.0
450	angle signal -	Current Pre	ediction: Cal	culating H	z
25 0.0	0.2	0.4	0.6	0.8	1.0



• Sensor Fusion for Remote Vital Sign Monitoring:

- Radar-Based HR & RR Detection
- Thermal Imaging for Hemorrhage Detection
- LiDAR & Optical for Casualty Localization
- Bayesian Inference Models for Injury Classification:
 - Predicts hemorrhagic shock probability
 - Prioritizes patients for medevac
- Alignment with NDIA Vital Signs 2025:
 - Enhancing Al-driven sensing for rapid battlefield assessment
 - Addressing DoD's gaps in scalable AI integration

Additional Application and Promise of Foundation Models: Reduced dependency on data



Your Data, Your MOMENT



Support for all (?) Time Series Use Cases

Leveraging Pittsburgh Supercomputing Center & Bridges-2 for AI Training

- Training Vision-Language Models (VLMs) on multimodal imagery.
- Utilizing AM-RADIO to enhance human detection and tracking.
- Improving instance tracking with DINO and SAM.
- Exploring decision-making strategies using single vs. multiple frames.
- Enhancing robot navigation in austere environments.



Yolo 11x fine-tuned on ~60k thermal images

CI/CD for Medical AI – Ensuring Rapid Deployment & Adaptability



- Ensures:
 - Automated Data Preprocessing & Training
 - Cross Validation for Model Selection
 - Automated Deployment of the Best Model to Production
- This combination is particularly useful in autonomous systems, where AI models must be continuously updated and validated before being deployed in real-world environments.

Key Takeaways







AI-ENHANCED TRIAGE SYSTEMS OPTIMIZE HUMAN PERFORMANCE WHILE MAINTAINING WARFIGHTER SAFETY. AI & ROBOTICS ENHANCE BUT DO NOT REPLACE HUMAN DECISION-MAKING IN COMBAT MEDICINE.



HUMAN-AUTONOMY TEAMING REDUCES COGNITIVE BURDEN THAT WILL ENABLE FASTER, MORE ACCURATE CASUALTY TRIAGE.





HSI ENSURES AI-ENABLED MEDICAL SYSTEMS ALIGN WITH WARFIGHTER NEEDS AND MAINTAIN DOD POLICY COMPLIANCE. INDUSTRY, ACADEMIA & DOD PARTNERSHIPS ARE NEEDED TO SCALE AND INTEGRATE AI-DRIVEN TRIAGE AND TACEVAC SOLUTIONS.



Thank you!